Ocean Acoustics and Signal Processing for Robust Detection and Estimation

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LONG TERM GOALS

The long term goal of this project is to develop efficient inversion algorithms for successful estimation and detection by incorporating (fully or partially) the physics of the propagation medium. Algorithms will be designed for robust ASW localization and detection and also for geoacoustic inversion.

OBJECTIVES

1. Achieve accurate and computationally efficient source localization by designing estimation schemes that combine acoustic field modeling and optimization approaches.

2. Develop methods for passive localization and inversion of environmental parameters that select features of propagation that are essential to model for accurate inversion.

APPROACH

During the past year, the focus of our research was on inversion using pulse dispersion in the ocean, **tabu** optimization for source localization and geoacoustic inversion, and maximum a posteriori estimation of time delays and amplitudes in a shallow water, multipath environment using Gibbs sampling.

Pulse dispersion was studied and modeled using high-resolution time frequency distributions in collaboration with Dr. Leon Cohen, Hunter College, City University of New York. In addition to the traditional spectrogram, which only provides an approximation to the dispersion effects of the waveguide, we investigated the potential of Wigner distributions, which are known to lead to exact dispersion relations [1].

The optimization work using tabu was performed in collaboration with Urmi Ghosh-Dastidar, recipient of a 2001 ONR graduate traineeship award. Tabu is an optimization approach widely used with great success in operations research [2]. Results from application of tabu to seismic data [3] indicated the potential of the method for source localization and geoacoustic inversion.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE
Ocean Acoustics and Signal Processing for Robust Detection and Estimation

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Mathematical Sciences,,New Jersey Institute of Technology,,Newark,,NJ, 07102

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Further worked was carried out in ray path identification which is often helpful or even necessary in shallow water multipath environments. The Gibbs sampling Maximum a Posteriori estimation scheme the PI has developed was further extended in collaboration with Michele Picarelli; the method estimates time delays and amplitudes through the numerical computation of the joint posterior probability density function of all unknown parameters, which is difficult to track analytically. This distribution is constructed through iterative sampling from conditional distributions of the involved parameters. During the past year the method was extended for the case of an unknown number of rays arriving at the receiver and a noisy environment of uncertain variance. The method was evaluated through comparisons to conventional time-delay estimation methods.

RESULTS

Our dispersion work showed that Wigner distributions are superior to spectrograms for dispersion curve modeling in a high signal to noise ratio environment. Although in such environments, Wigner representations offered a better resolution than spectrograms, they appeared to be vulnerable and have a poor performance in noisy environments. Modified Wigner distributions, however (quasi-Wigner distributions, [4]), appeared to maintain the high resolution property while losing the susceptibility to noise and interference. Figure 1 shows the Wigner representation (top), the quasi-Wigner representation (middle), and the spectrogram for a single propagating mode in a noise, shallow water environment. Both Wigner distributions show clearly the time frequency characteristics of the mode. The traditional Wigner distribution, however, exhibits an increased sensitivity to noise which can affect the estimation of dispersion properties. This sensitivity is suppressed in the quasi-Wigner distribution. The spectrogram, on the other hand, provides us with a coarser image of the propagating signal.

Results from tabu inversion showed that the method has the potential for efficient and accurate estimation of source location and geoacoustic parameters. Preliminary comparisons showed that tabu was more efficient than several variants of conventional and fast simulated annealing. As also pointed out in [3], tabu goes very deeply into local maxima and often results in more accurate estimates than other global optimization approaches.

The Maximum a Posteriori time delay estimation method was compared to a simple matched filter, a simulated annealing approach, and the expectation-maximization (EM) method that has been widely used for time delay estimation [5]. Both simulated annealing (suggested for time-delay estimation in [6]) and Gibbs sampling approaches performed better than the suboptimal (in the case of closely spaced arrivals) matched-filter; EM, being a local method, had a performance highly dependent on initial conditions. In terms of efficiency, the Gibbs sampling approach demanded significantly less computational time for convergence than simulated annealing. EM was the fastest approach but frequently diverged.

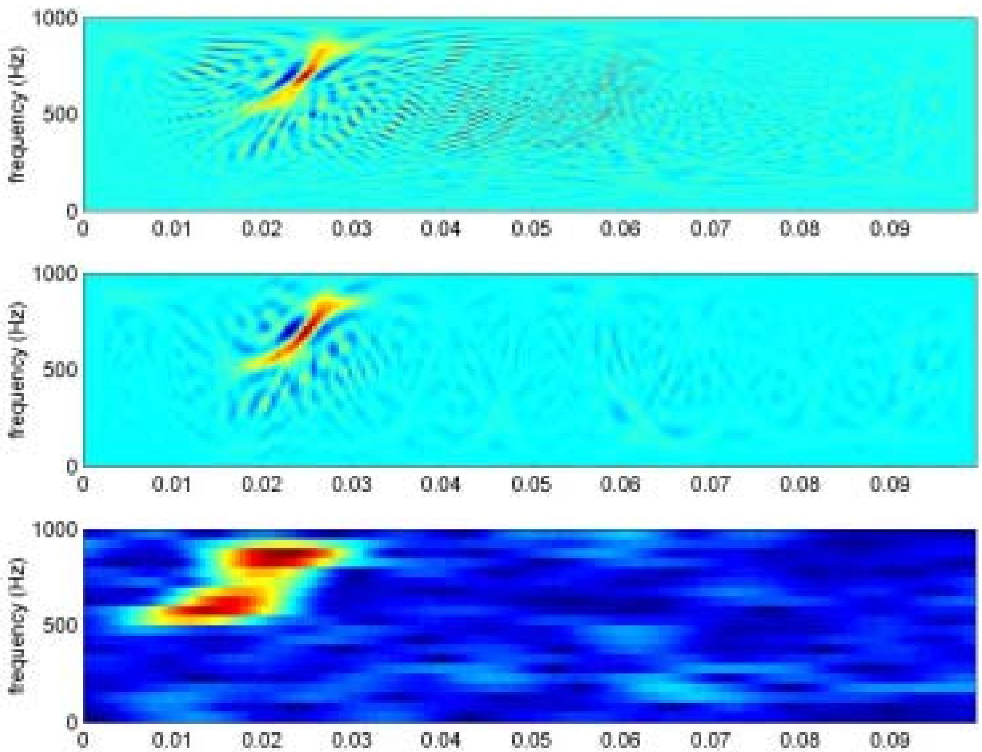

Figure 1: Wigner, Quasi-Wigner, and spectrogram representations of a mode propagating in a noisy, shallow water environment.

IMPACT

The methods developed in this project facilitate both passive and active localization and geoacoustic inversion in the ocean.

The results from our dispersion study showed that there are powerful high-resolution, time-frequency tools that can be used for fast inversion. More research will address how such distributions can be optimally used both for fast localization and geoacoustic inversion purposes, obviating the need for full-field matching.

Tabu was shown to be very successful in inversion with underwater sound. It operated efficiently and gave excellent parameter estimates. Tabu is a very flexible method that employs memory in various ways; the approach can be further improved by exploring memory more thoroughly for faster and more accurate estimation.

The Gibbs sampling-maximum a posteriori arrival identification approach approximates the optimal maximum likelihood approach [7] without the same computational demands; the method gives accurate estimates of time delays and amplitudes, whereas it also provides an estimate of the posterior probability distribution of those parameters (most time delays and amplitude estimation techniques only give point estimates). The extensions to the method during the past year are particularly useful,

because they will allow the application of the approach to real data, where both the noise variance and the number of expected arrivals are typically unknown. Accurately estimating arrival characteristics of distinct paths will facilitate the implementation of localization methods such as those in [8, 9, 10].

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